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OUTER SATELLITE ATMOSPHERES: THEIR  
EXTENDED NATURE AND PLANETARY INTERACTIONS

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16. Abstract  Significant progress in model analysis of data for the directional features of the Io sodium cloud is reported and appears to provide some support for a satellite emission mechanism that is driven by a magnetospheric wind. A number of model calculations for the two-dimensional intensity morphology of the Io sodium (region B) cloud are compared with six observations of Murcray (1978). Results of this comparison support the tentative conclusions, reported last quarter, regarding the satellite emission conditions, the role of the plasma torus and the sodium atom escape flux. Progress in updating the Titan hydrogen torus model is also discussed.			
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## I. SUMMARY OF RESEARCH PERFORMED IN THE THIRD QUARTER

Research activities in the third quarter have been directed (1) to continue modeling analysis of the directional features of the Io sodium cloud, (2) to provide further comparison of data for the two-dimensional intensity morphology of the region B sodium cloud with model calculations including the oscillation of the plasma torus, and (3) to further the investigations of the neutral hydrogen distribution in the magnetosphere of Saturn and its relation to Titan and other possible gas sources.

### 1. Directional Features of the Io Sodium Cloud

The new sodium cloud model, including the oscillating plasma torus, has continued to be used this quarter to study the peculiar directional feature data of Pilcher (1982) with whom a collaborative effort for this purpose has been established. The basic idea currently under evaluation is to determine if the time varying character of the directional features observed on the sky plane can be understood in terms of a gas source produced by the magnetospheric wind moving past Io and a time-space varying sodium sink produced (through electron-impact ionization) by the plasma torus as it oscillates about the satellite plane.

A new and more elaborate procedure was devised and implemented this quarter to analyze the relationship between the model-calculated, time-varying D-line intensity probabilities on the sky plane and the vector orientation of sodium atoms emitted from Io. The procedure was then applied to model calculations appropriate to the observed magnetic  $\lambda_{III}$  coordinate and the satellite geocentric phase angle for three sky plane images of the directional feature supplied to us by Pilcher in our ongoing collaborative effort. The three images were part of a four image sequence measured on January 6, 1980 which documented the feature changing its direction from south to north on the satellite plane in a period of four hours.

The analysis procedure showed that to produce a more dominant south to north intensity probability on the sky plane and to have the south-to-north phase change observed, the atom emission velocities from Io would have to have some limited angular dispersion that is approximately centered at right angles to the direction of the magnetospheric wind past the satellite. This conclusion is similar to an independent study by Dr. Robert E. Johnson (Univ. of Virginia) and his graduate student, Edward Sieveka who have shown, through elastic collisional calculations for moving ions and stationary neutral sodium atoms, that sodium is preferentially scattered at nearly right angles to the ion flux. Our analysis procedure also suggests that more atoms may be scattered near the equator than near the poles of the satellite. In order to better define the character of this latitudinal dependence

and the velocity dispersion of the high speed sodium emitted by Io, further analysis and comparison of model calculations with other sky plane images of Pilcher are required.

## 2. Region B of the Io Sodium Cloud

The sodium cloud model, including the oscillating plasma torus but excluding solar radiation effects, has continued to be used this quarter to calculate the two-dimensional intensity morphology of the cloud on the sky plane. Initial efforts reported last quarter, where one observation by Murcray (1978) was compared to our model results, have been expanded. A sequence of 10 images of the region B cloud measured by Murcray on January 27, 1977 is under study and model runs appropriate to six of these observations have been performed this quarter. The three tentative conclusions reported last quarter, based upon only one observation of Murcray, have been further confirmed by the six model runs this quarter. These three conclusions are stated below:

- (1) the presence (at non-critical Io phase angles) of a predominantly forward sodium cloud and the absence of a predominantly trailing sodium cloud may be understood in terms of an isotropic emission of sodium from Io and the radial structure of an oscillating plasma torus which produces a very asymmetric electron-impact ionization sink for sodium

- (2) the length of the forward sodium cloud is determined naturally by the plasma torus and occurs when the orbital paths of sodium atoms in the forward cloud have their second ionization encounters with the plasma torus somewhat ahead of Io
- (3) the flux of sodium from Io necessary to produce the measured two-dimensional intensity morphology of the B-cloud and also the much larger intensity values very near Io is approximately  $5 \times 10^8$  atoms  $\text{cm}^{-2} \text{sec}^{-1}$  (i.e., a total source of about  $2 \times 10^{26}$  atoms  $\text{sec}^{-1}$ , with a more refined value to be achieved when a more explicit description of the initial exospheric velocity dispersion is deduced or otherwise measured).

Model calculations performed this quarter for the six observations also exhibit  $\lambda_{\text{III}}$  dependent structure in the forward cloud. Some of the observations of Murcray also seem to suggest slight  $\lambda_{\text{III}}$  dependence in the forward cloud. Improved sky plane images, such as may be available from Goldberg (1983), are however required to ascertain if the model  $\lambda_{\text{III}}$  dependence has a true counterpart in the data.

In addition to the model runs, the computer code has been improved by rearranging information inside of Cray 1 vector loops so that the CPU execution speed is now about 30% faster. Further potential improvements to the code are also under evaluation.



### 3. Neutral Hydrogen Distribution in Saturn's Magnetosphere

Progress this quarter has been made in obtaining information to describe the plasma in the Saturn magnetosphere. New information for the density and temperature of the protons, heavy ion and electrons has been acquired from the Voyager PLS group (McNutt, 1983). Additional information is however needed in order to be able to adequately calculate the lifetime of H atoms in the Saturn environment. In addition to this, an analytical fit for the electron impact ionization of H has also been acquired (Shemansky, 1983) for use in updating the Titan torus model. Efforts to incorporate this information into the old code have been initiated and will be pursued more fully in the next quarter.

## II. PROGRAM FOR THE NEXT QUARTER

Research activities in the next quarter will provide (1) further model studies of the directional features of the Io sodium cloud in an effort to understand the exospheric conditions that are important in their formation, (2) more model calculations for the two-dimensional morphology of the Io sodium (region B) cloud and comparisons of model results with observations to further evaluate the three conclusions reported herein, and (3) additional progress in modifying the Titan hydrogen torus model to include



the spatial lifetime structure of H atoms in the Saturn magnetosphere.

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